SPECIFICATIONS

Scanning Probe Microscope (SPM) System with Control Electronics and Accessories

The Naval Research Laboratory (NRL) has a requirement for a highly flexible research grade Scanning Probe Microscope (SPM). The system shall meet or exceed the following specifications:

1. System capabilities

1.1 This instrument shall be capable of measuring topographic, magnetic, and electrical properties of various materials. The SPM shall be able to perform the following modes of operations: Contact Atomic Force Microscopy (AFM), Non-contact AFM, Lateral Force AFM, Tapping Mode AFM, Electric Force Microscopy, Magnetic Force Microscopy, Surface Potential Microscopy, Scanning Tunneling Microscopy (STM), Force- Volume Imaging, Phase Imaging Contact AFM and Tapping Mode AFM in fluid.

2. System Controller and Electronics Interface

2.1 The system shall have three independent 16 bit digital to analog converters (DACs) per scan axis (x, y, and z for a total of 9). On a per scan axis basis one DAC is used to scale scan size, the second DAC is used to scale scan pattern, and the third DAC is used for scan offset.

2.2 The digital resolution of the scan shall be independent of the scan size and offset, allowing the use of a single large area scanner (<90 microns) for very small scans (<50nm) anywhere with in the maximum scan range of the scanner with no artifacts caused by quantization or alisasing. This allows the operator to use a single scanner for imaging an area as great as 90 microns, and then "zooming" in (decreasing scan size) and offsetting the probe to an area of interest for a high resolution scan.

2.3 The feedback control of the tip-sample separation shall be digital.

2.4 Sampling with 16 bits of resolution and a sampling rate of 50kHz or greater is required in the control loop. This ensures that a real-time microscope control can be maintained at sufficient speed to help prevent tip crashes.

2.5 The feedback and scan drive functions shall have a lateral scan rate of >500 microns per second with a 90 micron or greater scanner, with real-time scan linearization active.

2.6 Disable/enable slow scan axis for optimizing feedback parameters along a single line scan. The system shall allow logarithmic (STM) or linear (AFM) feedback response, and provide the capability to select from the following input filters and gain types: integral, proportional, and digitally expressed functions. These input filters shall include the ability to perform real-time scan linearization and to utilize the information from the preceding scan to allow the tip to anticipate features in the current scan (2-D, also known as look-ahead gain). The "look-ahead" gain feature is extremely useful for those specimens which have a periodic structure.

2.7 The user shall be able to set the following scan and probing parameters, both before and during scanning:

- Scan rate
- Feedback, integral, proportional, and 2-D
- Scan size
- Scan offset
- Samples per scan line; 128, 256, 512
- User selectable scan lines per image; from up to 512 lines
- Set point; bias voltage, cantilever deflection
- Input filter
- Input mode; log or linear
- Operating mode; constant height or constant feedback parameter

2.8 The system shall provide real-time simultaneous display of at least three images or scope traces consistent with the data acquisition mode. These images may be topography, auxiliary channel, force volume, lateral force (LFM), or real –time linearized scans in either trace or re-trace scan directions.

2.9 The system shall be able to initiate data capture and go in to off-line analysis mode with out interrupting data capture.

2.10 The system shall provide the capability to capture at least 30 Mbytes of data before archiving is required.

2.11 The operating environment for the scanning probe microscope control interface shall be Windows-NT, allowing for real-time response and data processing off-line on a desktop. Windows-NT enables the system to use true 32 bit processing with pre-emptive multitasking, which is preferred or instrument control when compared to cooperative multitasking found in Windows-95 or Windows-98 operating system.

2.12 The system shall have a real-time linearization which provides a calibrated non-linear waveform to the piezoelectric scanner achieving a linear output for all scan sizes (2 nanometers to 90 microns) and scan rates.

2.13 The system shall provide an option to perform non-square scans of the specimen surface. The aspect ratio for these non-square scans shall be user selectable from 1:1 to 1:32. This feature enables efficient operation of the microscope.

2.14 The system shall provide the ability to perform a lift mode operation when measuring long-range force field gradients emanating from the sample surface. Examples of these long-range force field gradients are electric/coulombic forces and magnetic forces. The lift mode shall work as follows: topography is determined on the first pass over a scan line, then the tip is lifted some user defined height off the surface and the exact same scan line is traced again, keeping a constant (user defined) separation between tip and sample surface. During this second pass, the tip interacts with, and measures, the long-range force field gradient. The use of this mode virtually eliminates any convolution of topographic features with the desired force gradient information. Other methods, which simply skim the tip some height above the sample with out regard to topography, suffer from this convolution effect, making the resultant data difficult to interpret.

3. Scan Head Performance

3.1 The scanner shall be capable of providing a three dimensional motion (x,y,z) of the probe relative to the sample surface. The scanner shall have a >90 micron scan range in x and y, and a greater than 5 micron vertical (z) range.

3.2 The system shall provide a piezoelectric ceramic tube scanner constructed of two piezo tubes bonded together. The piezoelectric ceramic material used in these tubes shall be optimized for sensitivity and linearity during the x, y, and z motion of the scanner. This design shall provide <1% change in z piezo sensitivity ("derating") for a 5 angstrom step height after calibrating the scanner with a 180 nanometer standard calibration reference.

3.3 The scan head design shall incorporate an easily changeable cantilever holder. For tip oscillation modes (such as Tapping Mode AFM, Electric Force Microscope, Phase Imaging , etc.), the oscillation of the probe shall be user selectable over a range of RMS amplitudes from DC to over 500 nanometers peak-to-peak, and at frequencies from DC up to 1 MHz.

4. Optical Video Microscope

4.1 The system shall include a video microscope that allows for an on-axis view of the tip and sample surface. This is critical for aligning the tip over feature of interest.

4.2 The optical video microscope shall have these minimum performance specifications: 450x magnification, brightfield Koehler illumination with adjustable aperture and field diaphragms, 13 inch color monitor for image display.

5. Vibration Isolation

5.1 A vibration isolation platform must be provided suspended by elastic cords.

6. Tapping Mode Operation

6.1 Tapping mode AFM shall operate in the following manner: the probe is moved laterally relative to the surface of the sample, and simultaneously, is repeated lifted off the surface and returned to the surface. The repeated lifting avoids the probe dragging across the surface, thereby minimizing damage to the probe or sample, and eliminates distortion caused by stick-slip motion.

7. Magnetic Force Microscopy

7.1 Magnetic force microscopy shall incorporate a dual scanning lift mode operation whereby the topography is fully deconvolved from the magnetic force gradient signal.

7.2 A variety of magnetic probes shall be available from the vendor in order to match the properties of the probe to that of magnetic sample.

8. Upgrades, Installation, and Training

8.1 The system shall have the capability to be upgraded in the future so that other modes of operation can be implemented. These modes may require some hardware upgrade, but shall not require a separate computer and/or control electronics. These modes include: Scanning Thermal Microscopy and Nanoindentation.

8.2 The vendor shall provide a minimum of two days on site training after installation of the system.

9. Manuals

8.1 The system shall include all manuals (operation and maintenance), cables and interconnects.